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Review

# Vegetable production in the Red River Delta of Vietnam. I. Opportunities and constraints

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ABSTRACT

An overview is given of the natural, socio-economic, agronomical and marketing conditions for vegetable production in the Red River Delta (RRD) of Vietnam. The seasonal variation in temperature in the RRD is the main determinant for the production season of vegetables. Heavy rainfall in the hot season increases production risks, as it may physically damage crops. Frequent rainfall in this period may enhance disease incidence. Landholdings are small and individual plots are the smallest of Indochina. Vegetables typically are produced in flooded rice based systems. Such systems are characterized by poor soil structure for vegetable production and high labour demand for the construction of raised beds. Highly perishable crops can only be grown close to the markets in the peri-urban areas. Less perishable crops can be produced further away from the city markets. Generally, large quantities of pesticides are used and there is increasing public concern about pesticide residues on products. The small landholdings, small plots and consequently the small amounts of product, limit effective marketing and make the producers dependent on collectors. Given the trends in population dynamics and human diets, urban vegetable demand in the RRD, however, has ample opportunities to grow.

Effects have been analysed and categorised in opportunities and constraints for adopting improvements. A potential pathway to sustainable development is the development of permanent vegetable production systems, with producers co-operating in producers organizations, enabling them to work on a larger scale, produce larger volumes, introduce harvest date planning and quality control and aim for the integration of production with marketing in a vegetable value chain. By simultaneously adopting Good Agricultural Practices, consumers' food safety concerns can be addressed. The expected increase in vegetable demand is likely to open new opportunities for the RRD vegetable producers.



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## 1. Introduction

The global demand for vegetables is increasing. Global vegetable consumption, as defined by FAO [1], has increased from 190 million Mg in 1961 to 880 million Mg in 2009, because (1) the global population has increased from 3.1 billion in 1961 to 6.8 billion in 2009, and (2) the daily vegetable intake has increased from 170 g per capita per day in 1961 to 360 g per capita per day in 2009 [1]. The daily vegetable intake is increasing because of a growing awareness of the important positive effect of vegetables on health, and because of a demand for year-round availability and diversity of foods [2].

Continuing urbanization and increasing welfare in the cities result in an increasing year-round demand for commercially produced vegetables [3,4]. With populations of about 9 million for Jakarta [5] and 5 million for Ho Chi Minh City [6], these cities may serve as examples to illustrate the considerable amounts of vegetables needed to supply such huge cities. With an average vegetable consumption in the beginning of the previous decade of 70 g per capita per day for Indonesia, and 220 g per capita per day for Vietnam [1], the daily vegetable demand is estimated to be 630 Mg for Jakarta and 1100 Mg for Ho Chi Minh City, excluding the waste removed from the product before preparation.

A typical example of a vegetable production area close to a very large city is the Red River Delta (RRD) in Vietnam. The RRD is the economic centre of northern Vietnam with Hanoi as the major city. It consists of 9 provinces (Fig. 1). With an area of about 1,500,000 ha, equalling 13% of the total area of Northern Vietnam, the RRD was responsible for 63% of the agricultural output and for 81% of the industrial output of Northern Vietnam in 2005 [6]. Rice is the principal crop of the delta, but many kinds of vegetables are also grown. The RRD comprises 25% of Vietnam's vegetable-producing area and was responsible for 30% of the total vegetable production in Vietnam in the period 2002–2005 (General Statistic Office (GSO), unpublished data). Vegetables are important cash crops in the RRD, whereas rice is mainly used for home consumption [7,8]. In the RRD, income from vegetable cultivation comprises 83% of the income from crop production in peri-urban areas and 89% in rural areas [8].

As in many other countries of South-East Asia, in Vietnam field-grown vegetables are often rotated with flooded rice. Despite the potential profitability of vegetable production, this rotation has disadvantages. Wet puddling, necessary for flooded rice, affects soil structure, resulting in restricted water movement in the soil, making the soil less suitable for vegetable production [9,10]. In addition, labour requirements in this rotation are high, caused by laborious practices such as raised bed construction for vegetable production, and flattening and puddling of the soil for rice production after vegetable cultivation [11].

Notwithstanding the disadvantages of the current rotations, vegetable farming can be lucrative in the RRD, as shown by the fact that the output value per labour-day of vegetable production was 2.2 times higher than that of cereal production [12]. However, seasonality of production and price fluctuations [13] are significant problems vegetable farmers and consumers currently face.

The purpose of this paper is (1) to provide an overview of the natural, socio-economic, agronomical and marketing conditions for vegetable production in the RRD, and (2) to analyse and formulate pathways for sustainable development.

## 2. Natural conditions for vegetable production in the Red River Delta of Vietnam

### 2.1. Climate and its effects

The RRD is situated around 21° N latitude. According to Köppen's climate classification, the RRD has a tropical monsoon climate. Hanoi's climate is representative for the RRD (Table 1).

The climate of the RRD comprises three seasons: (1) the hot and wet season from May to September, (2) the cool and dry season from October to January, and (3) the cool and humid season from February to April. The hot and wet season is characterized by a high radiation, a high temperature, high rainfall, and moderate relative air humidity (RH). The cool and dry season has a moderate to low radiation, a moderate to low temperature, low rainfall, and a low RH. The cool and humid season has low radiation, a low to moderate temperature, low rainfall, and a high RH. Daylength varies from 10.50 h to 13.20 h during the year [14]. Daylength is longest in the hot and wet season.

The growing season for vegetables in the Red River Delta is mainly determined by temperature. Vegetables of temperate origin, such as broccoli (*Brassica oleracea* var. *italica*) and carrot (*Daucus carota*) grow well in the cool season. Tropical leafy vegetables such as Ceylon spinach (*Basella rubra*) and fruit vegetables of the *Cucurbitaceae* family grow well in the hot season.

During the hot season, rainfall generally is sufficient for crop growth. During the cool season, with limited rainfall, crops are mostly irrigated. Heavy rainfall in the hot and wet season may cause physical damage to the vegetables. Although not documented in literature, it is known that heavy rainfall may even completely destroy vegetables in the field, making vegetable production in the hot season more risky. In cases of extreme and prolonged rainfall, flooding may occur, resulting in complete loss of production [15]. For example, the flood in Hanoi and some northern provinces from 29 October to 5 November 2008 destroyed large quantities of vegetables and caused a sharp increase in the price of vegetables in Hanoi (Fig. 2).

Temperature, rainfall and RH influence the incidence and abundance of diseases and pests in vegetables. The climate allows year-round occurrence of bacterial wilt (*Ralstonia solanacearum*) on tomato (*Solanum lycopersicum*) [16], whereas late blight (*Phytophthora infestans*), because of its sensitivity to high temperatures, is common on tomato only in the cool seasons. However, late blight in the cool and humid season is more serious than in the cool and dry season [17], because of the high RH in the cool and humid season. Flea beetle (*Phyllotreta striolata*) and white fly (*Bemisia tabaci*) are abundant in the hot and wet season, whereas diamondback moth (*Plutella xylostella*) is more abundant in the cool season [17]. Flea beetles and white flies prefer high temperatures, whereas diamondback moth cannot withstand high intensity rainfall. Frequent

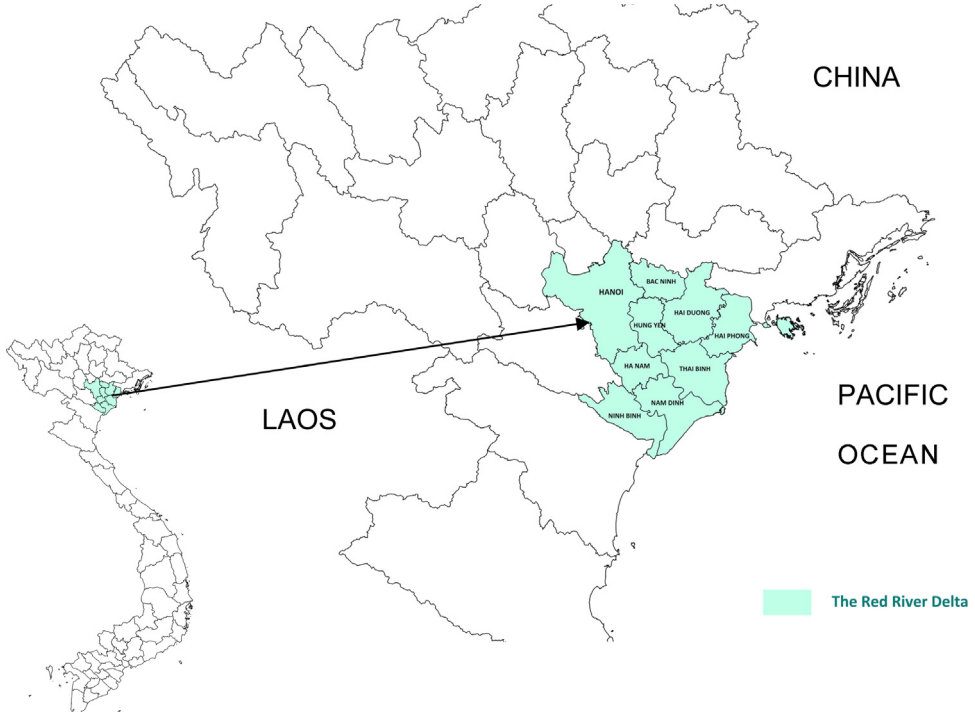


**Fig. 1.** Location of Vietnam and the Red River Delta.

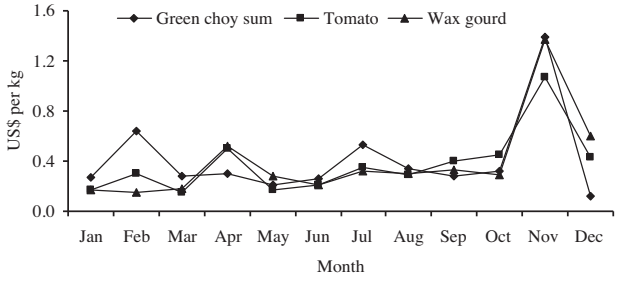


**Fig. 2.** Monthly price of green choy sum, tomato and wax gourd at Long Bien wholesale market in Hanoi, 2008 (Data courtesy of Fresh Studio, Da Lat, Vietnam).

rainfall in the hot and wet season may enhance disease infection by prolonging leaf wetness periods.

Although chemicals are often abundantly used to control pests and diseases [18], yield losses due to pests and diseases in the wet season are higher than those in the dry season [15].

In conclusion, among the climatic factors, temperature is most important for vegetable production as it determines the specific growing season. Heavy rainfall may damage crops physically. Shortage of rainfall is less important, as during dry periods, crops are irrigated. Specific pest and disease incidence may be seasonal.

### 2.2. Soils and their suitability for vegetable production

Most soils of the RRD are of the alluvial type and vary in soil texture due to irregular river tides. Interposed clay, silt or sandy layers are generally present. Soils near rivers usually have a sandy texture, but soils far from rivers may have a fine texture such as silt or clay. In general, the alluvial soils of the RRD are of medium texture, bright brown in colour and have a neutral pH. Generally, such soils are considered to be suitable for annual crops, including vegetables [19].

Locally, however, soil conditions may vary and be less favourable for vegetable production. The soils in the Dong Anh district, an important vegetable producing district of the RRD, generally have a sandy loam to medium loam texture, are mostly acid to medium acid and are low in organic matter and nitrogen (Table 2). The light soil texture, low organic carbon content and low cation exchange capacity of the top soil result in a low basic soil fertility, as well as in a limited water and low nutrient holding capacity [11,20]. In such cases the low soil fertility and low nutrient holding capacity of the soil may be compensated for by the repeated application of large amounts of fertilizer [21].

The climatic conditions in the RRD may influence the seasonal pattern of soil nitrogen availability. Soil nitrate accumulates in the root zone during the dry season when evaporation exceeds precipitation, and leaches beyond the root zone in the wet season when precipitation exceeds evapotranspiration [9]. Especially broadcast

**Table 1**
Mean monthly climate data for Hanoi over the period 1996–2006.

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature (°C) | 17.4 | 18.2 | 20.4 | 24.7 | 27.7 | 29.6 | 29.6 | 28.8 | 27.9 | 25.9 | 22.6 | 18.6 |
| Rainfall (mm per month) | 16 | 26 | 57 | 73 | 210 | 257 | 304 | 328 | 173 | 99 | 59 | 30 |
| Relative humidity (%) | 78 | 81 | 83 | 84 | 80 | 78 | 80 | 82 | 79 | 76 | 75 | 74 |
| Sunshine (hours per month $\geq 0.1\,kW\,m^{-2}$) | 68 | 49 | 44 | 91 | 157 | 159 | 163 | 149 | 154 | 150 | 137 | 102 |

Sources: The 1996–1998 data are from Lang Ha Meteo Station, Lang Ha Street, Hanoi, Vietnam (unpublished data). The 1999–2006 data are from Statistical Year Book 2000 - 2006 (General Statistic Office, 2001–2007).

**Table 2**
Physical and chemical properties of the top soil in two villages in the Dong Anh district of the Hanoi province [20].

| Parameter | | Village (soil depth) Son Du (0–19 cm) | Tang My (0–17 cm) |
|---|---|---|---|
| Soil texture | Sand (%) | 36 | 36 |
| | Silt (%) | 50 | 58 |
| | Clay (%) | 14 | 7 |
| pH KCl | | 5.0 | 6.5 |
| Organic carbon (%) | | 0.91 | 0.86 |
| N total (%) | | 0.09 | 0.09 |
| $P_2O_5$ total (%) | | 0.05 | 0.04 |
| $K_2O$ total (%) | | 0.39 | 0.25 |
| N available (mg per100 g soil) | | 2.80 | 2.80 |
| $P_2O_5$ available (mg per100 g soil) | | 6.24 | 4.12 |
| $K_2O$ available (mg per100 g soil) | | 12.70 | 3.37 |
| Cation exchange capacity (meq per100 g soil) | | 7.82 | 4.79 |

applied nitrogen fertilizer can be lost because of surface run-off during severe rainfall. Therefore, farmers may need to apply more nitrogen to vegetable crops in the hot and wet season with high rainfall than in the cool seasons with low rainfall, to maintain production levels.

In conclusion, generally, soils in the RRD are suitable for the production of vegetable crops. Locally less suitable soil conditions are overcome with adapted production methods. More fertilizer nitrogen may be needed under conditions of abundant rainfall.

## 3. Socio-economic conditions for vegetable production in the Red River Delta of Vietnam

In 2006, the RRD's population was 18.2 million, of which 13.7 million people were living in rural areas [6]. The rural population is increasing annually with 0.5%, while the annual population in the urban areas increases with 4.9%. By 2020 the RRD population is projected to be 13.9 million in the rural areas and 9.4 million in the cities. Since urbanization and industrialization will lead to a decrease in the area available for agriculture [8,22] agricultural production per unit of land will have to increase.

Vietnamese farmers returned to household-based production after two successive reforms (Decree 100 in 1981 and Resolution 10 in 1988). This gradually shifted agricultural production from co-operatives to individual households [23]. In the RRD, vegetables are mostly produced by small landholders. The average area of agricultural land per capita is approximately 700 $m^2$ [6]. The average size of vegetable plots in the RRD is 400 $m^2$, which is the smallest in Indochina [12]. Vegetable production on such

**Table 3**
Groups of vegetable crops according to growing season [11,25,26,42,43].

| Group/family | Crop | | Growing possibility[a] | |
|---|---|---|---|---|
| | Scientific name | Common name | Apr–Oct | Nov–Mar |
| Cool season crops | | | | |
| *Liliaceae* | *Allium ampeloprasum var. porrum* | Leek | 1 | 5 |
| *Liliaceae* | *Allium cepa* var. *cepa* | Onion | – | 4 |
| *Liliaceae* | *Allium cepa* var. *ascalonicum* | Shallot | – | 5 |
| *Umbelliferae* | *Apium graveolens* | Celery | 1 | 5 |
| *Cruciferae* | *Brassica oleracea* var. *italica* | Broccoli | – | 4 |
| *Cruciferae* | *Brassica oleracea* var. *capitata* | Cabbage | 1 | 5 |
| *Cruciferae* | *Brassica oleracea* var. *botrytis* | Cauliflower | – | 4 |
| *Cruciferae* | *Brassica oleracea* var. *gongylodes* | Kohlrabi | 2 | 5 |
| *Cruciferae* | *Brassica rapa* ssp. *Chinensis* | Green pak choi | 1 | 5 |
| *Compositae* | *Chrysanthemum coronarium* | Garland chrysanthemum | – | 5 |
| *Apiaceae* | *Coriandrum sativum* | Coriander | 1 | 5 |
| *Compositae* | *Lactuca sativa* | Lettuce | 2 | 5 |
| *Solanaceae* | *Solanum lycopersicum* | Tomato | 2 | 5 |
| *Leguminosae* | *Phaselus vulgaris* | French bean | – | 5 |
| *Leguminosae* | *Pisum sativum* var. *macrocarpon* | Snow pea | – | 4 |
| *Cruciferae* | *Raphanus sativus* | Radish | 3 | 5 |
| *Cucurbitaceae* | *Sechium edule* | Chayote | 1 | 5 |
| Hot season crops | | | | |
| *Basellaceae* | *Basella alba* | Ceylon spinach | 5 | 1 |
| *Cucurbitaceae* | *Benincasa hispida* | Wax gourd | 5 | 2 |
| *Malvaceae* | *Corchorus olitorius* | Tossa jute | 5 | – |
| *Cucurbitaceae* | *Cucumis sativus* | Cucumber | 4 | 2 |
| *Cucurbitaceae* | *Cucurbita moschata* | Pumpkin | 5 | 3 |
| *Cucurbitaceae* | *Luffa acutangula* | Loofah | 5 | – |
| *Cucurbitaceae* | *Momordica charantia* | Bitter gourd | 5 | – |
| *Leguminosae* | Vigna unguiculata ssp. *sesquipedalis* | Yard long bean | 5 | – |
| Year–round crops | | | | |
| *Amaranthaceae* | *Amaranthus tricolour* | Amaranth | 5 | 4 |
| *Liliaceae* | *Allium fistulosum* | Welsh onion | 4 | 5 |
| *Cruciferae* | *Brassica juncea* | Indian mustard | 4 | 5 |
| *Cruciferae* | *Brassica juncea* var. *rugosa* | Wrapped heart mustard | 4 | 5 |
| *Cruciferae* | *Brassica rapa* var. *parachinensis* | Green choy sum | 4 | 5 |
| *Convolvulaceae* | *Ipomoea aquatica* | Kangkong | 5 | 4 |

[a] – = no cultivation advised; 5 = very good cultivation possibility.

small plots may have advantages, such as intensive investment of labour. On the other hand, efficient mechanization is difficult.

In general, the usually small scale of farming operations has serious disadvantages. Small farms are typically operated by poor or part-time farmers, who may have difficulties to apply new technologies. In addition, small farmers usually have no strategy for harvest date planning and marketing of their products, especially in rural areas [7,15]. Small farmers tend to grow the previously successful crops of their neighbours, thereby increasing production of these crops and putting pressure on prices [7]. Especially in rural areas, farmers have no other option than to sell their product to collectors, who determine the price.

In conclusion, the small size of the farming operations and small plots limit the introduction of improved production and marketing systems.

## 4. Agronomical conditions for vegetable production in the Red River Delta of Vietnam

### 4.1. Production

#### 4.1.1. Season

The vegetables grown in the RRD can be grouped into three categories according to their growing season: (1) winter crops, suitable for the period November–March, (2) summer crops, especially suitable for the period April–October, and (3) vegetables grown year-round (Table 3). Winter crops are diverse and include root, tuber, fruit and leafy vegetables. They mainly belong to the *Cruciferae* and *Liliaceae*. Summer crops are less diverse than winter crops, and include fruit and leafy vegetables. The summer fruit vegetables mainly belong to the *Cucurbitaceae*. Year-round crops are mainly leafy vegetables, belonging to various botanical families.

The main season for vegetable production is from October to February. A study in five provinces of the RRD (Hanoi, Hai Duong, Hung Yen, Vinh Phuc and Bac Ninh) showed that the land area cropped with vegetables was 84% in that period and only 16% of the area was cropped with vegetables in the hot and wet season [12].

#### 4.1.2. Location

Vegetable production in the rural areas differs from that in the peri-urban areas. Peri-urban areas are generally defined as being located within such a distance from a city that farmers with common transport means are able to supply perishable vegetables within a day to city markets [8]. Highly perishable vegetables like Indian mustard (*Brassica juncea*), green choy sum (*Brassica rapa* var. *parachinensis*) and lettuce (*Lactuca sativa*) traded in Hanoi markets are from Hanoi peri-urban areas, whereas less perishable vegetables like wax gourd (*Benincasa hispida*), cabbage (*Brassica oleracea* var. *capitata*) and tomato are from both Hanoi peri-urban and rural areas [13].

This implies that the vegetables grown commercially in rural areas generally are of the low perishable type, whereas those grown commercially in the peri-urban areas are of both high and low perishable types.

#### 4.1.3. Type of production

In the RRD the acreage of vegetable production, as well as the vegetable yield per ha, increased in the period 2002–2005 (Table 4), likely following increased demand. As for the method of production two main types of vegetable production can be distinguished: (1) the so-called 'safe vegetable' production (with restricted inputs of pesticides and fertilizers) and, (2) conventional vegetable production (with often high inputs of pesticides and fertilizers). Because of the very limited area of organic vegetable production, this type of production is not taken into consideration.

**Table 4**
Yield, area and total production of vegetables in the Red River Delta during the period 2002–2005 (General Statistic Office, 2003–2006).

| Year | Yield (Mg ha$^{-1}$) | Area (ha) | Total production (Mg) |
|---|---|---|---|
| 2002 | 16.3 | 142,000 | 2,300,000 |
| 2003 | 16.5 | 149,000 | 2,460,000 |
| 2004 | 17.3 | 160,000 | 2,770,000 |
| 2005 | 18.0 | 159,000 | 2,850,000 |

Due to public pressure concerning the safety of vegetable products, especially regarding the presence of pesticide residues on the products, the Ministry of Agriculture and Rural Development has implemented a 'safe vegetable' production programme since 1995. The programme educates farmers to grow vegetables with restricted inputs of pesticides and fertilizers and stimulates the use of water from wells or non-polluted rivers [24].

The training programme is based on production protocols provided by the Hanoi Department of Agriculture and Rural Development, the Fruit and Vegetable Research Institute, or the Hanoi Plant Protection Department. 'Safe vegetable' production is mostly found in peri-urban Hanoi and in the Soc Son district of Vinh Phuc province. As a result, trained 'safe vegetable' farmers' knowledge on pesticide toxicity classification and on the use of pesticides has been improved [18].

Conventional vegetable production is the type of production based on producers' experience and expertise. For conventional vegetables, quality standards, and quality control, are virtually absent. Because of the small landholdings, farmers tend to overuse fertilizers and pesticides in order to maximize crop yield [24].

There are no data available on the areas of 'safe' and conventional vegetable production in the whole of the RRD. In Hanoi province, 'safe vegetable' production covered 30% of the total vegetable production area in 2001 [24].

In conclusion, season and location influence the type of vegetable crops produced. Lack of adequate cool storage and transport facilities limits the production of perishable crops to the peri-urban areas. Public health concern is instrumental in stimulating reduction of pesticide and fertilizer use.

### 4.2. Crop rotation

Vegetable crop rotations vary throughout the RRD. Documented data on vegetable crop rotations are scarce, but for the districts Vu Thu and Thuong Tin descriptions of vegetable crop rotations are available.

In the Vu Thu district of the Thai Binh province, there are four common crop sequences [25]:

1. Rice–rice–fallow.
2. Rice–rice–lettuce–lettuce–fennel (*Foeniculum vulgare*).
3. Groundnut (*Arachis hypogaea*)–caisin (*Brassica parachinensis*)–Indian mustard–kohlrabi (*Brassica oleracea* var. *gongylodes*)–radish (*Raphanus sativus*)–coriander (*Coriandrum sativum*).
4. Coriander–lettuce–shallot (*Allium cepa* var. *ascalonicum*)–Indian mustard–welsh onion (*Allium fistulosum*)–coriander–lettuce–lettuce.

The profitability of sequence 2, i.e., rice in the hot season and vegetables in the cold season, has been 5.2 times that of sequence 1. Although the profits of sequences 3 and 4 were again considerably higher than that of sequence 2–especially the profit of sequence 4 was 2.1 times that of sequence 2 and even 10.6 times that of sequence 1–sequence 1 and sequence 2 covered 26% and 66% of

agricultural land in the district, respectively. Sequences 3 and 4 are not implemented more often because of (1) a less predictable production compared with rice, resulting in higher risks for the producer, (2) insecurity about the ultimate product price and, (3) because of higher labour needs with vegetable cultivation. On a national scale, the continuous emphasis on food security, i.e., rice production, also plays a role.

In the Thuong Tin district of Hanoi province, most of the farmers grow vegetables year-round to supply the Hanoi market. Farmers grow other food crops if their land is not suitable for vegetables or if their labour availability is insufficient for vegetable production. Leafy vegetables with a short growth duration, such as Indian mustard, green choy sum, green pak choi (*Brassica rapa* ssp. *Chinensis*), garland chrysanthemum (*Chrysanthemum coronarium*), leek (*Allium ampeloprasum* var. *porrum*), and coriander are commonly grown in this area [26].

Especially crops of the *Brassicaceae* family are grown year-round in both Vu Thu and Thuong Tin districts, resulting in the continuous presence of family-specific pests and diseases [25,26].

In conclusion, year-round vegetable production may be limited by perceived production and marketing risks, and because of higher labour needs. On the other hand, vegetable crops grown in continuous vegetable sequences, especially with a high number of species of the same family, may possibly suffer more from biotic stress than crops grown in rotation with the traditional food crops.

## 5. Marketing conditions for vegetables produced in the Red River Delta of Vietnam

### 5.1. Demand and supply

Vegetable consumption in urban Hanoi is on average 270 g per capita per day [27]. Hanoi with an urban population of 2,101,600 people [6] thus requires about 570 Mg per day. This is excluding the waste that is removed from the product before preparation. So the ultimate daily demand is even higher. All the other cities of the RRD with a total urban population of 2,445,200 [6] require about 660 Mg per day.

Vegetable consumption is lowest in June and July and highest in February and March [27]. This variation appears to be related to the seasonality of vegetable supply. Supply of temperate vegetables such as cabbage and Chinese cabbage is strongly seasonal [13]. In the period November–March large amounts of these vegetables produced in the RRD are sold at wholesale markets, whereas in June only small amounts of these vegetables, imported from China, are sold at wholesale markets. Vegetables grown year-round in the RRD, such as green choy sum, however, are sold in large amounts in August, the more difficult time for temperate vegetable production (Table 5).

**Table 5**
Quantity (Mg) of three vegetables sold daily in wholesale markets in Hanoi over the period March 2002–January 2003) [13].

| Month | Cabbage | Chinese cabbage | Green choy sum |
|---|---|---|---|
| March | 20.7 | 6.3 | 11.4 |
| June | 6.5 | 0.4 | 11.7 |
| August | 17.7 | 0.0 | 26.2 |
| November | 36.3 | 5.9 | 18.3 |
| January | 30.3 | 3.4 | 11.0 |

In conclusion, the amount and type of vegetable consumption appears to be related to the seasonality of vegetable supply.

### 5.2. Marketing channels

Vegetable marketing studies in the RRD generally focus on Hanoi. When divided according to production method, the two types of products, i.e., 'safe vegetables' and conventional vegetables, are traded in Hanoi with partly overlapping marketing channels.

'Safe vegetables' are traded through co-operatives, collectors or distribution companies to 'safe vegetable' shops or supermarkets (Fig. 3). Although 'safe vegetable' production covered 30% of the total vegetable production area in Hanoi in 2001 [24], the share of 'safe vegetables' sold through 'safe vegetable' shops and supermarkets is only 8% [28]. This is because only part of the 'safe vegetable' products is sold to schools, restaurants, supermarkets, factories or retail stalls. The remaining part is sold in free markets. For instance, in 2010, the Van Duc co-operative, near Hanoi, produced 'safe vegetables' on 286 ha, but only 15% of the products could be sold directly to schools, restaurants, hotels and factories. The remaining part was sold in free markets at conventional vegetable prices, which were only about 75% of the 'safe vegetable' prices [29].

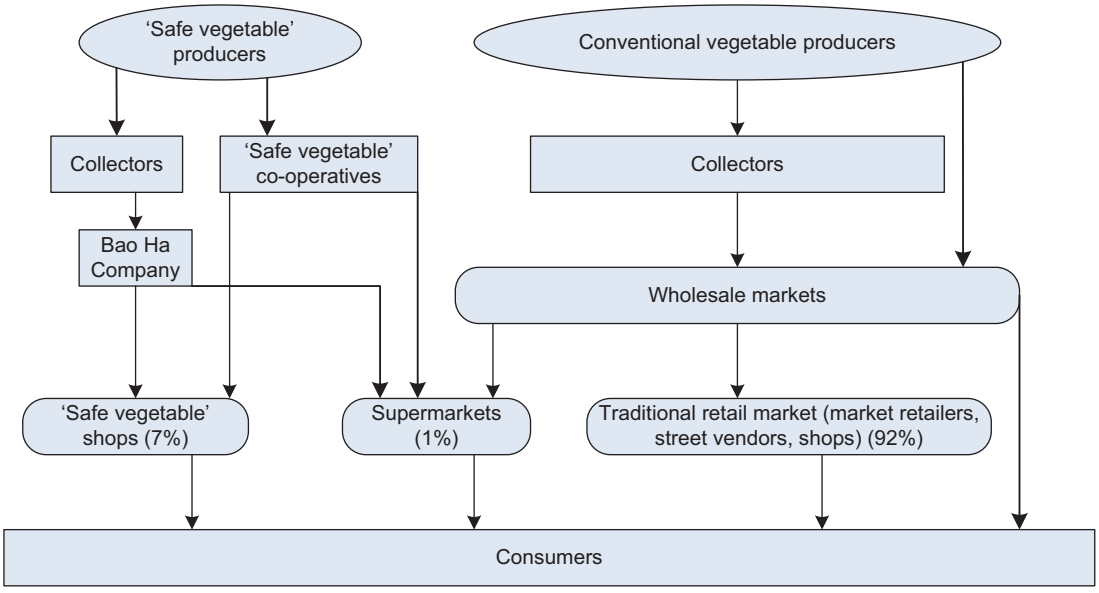


**Fig. 3.** Marketing channels and market share (%) for vegetables in urban Hanoi (Adapted from [28]).

**Table 6**
Monthly price indexes[a] of vegetables sold in Hanoi over the period 1996–2001 [15].

| Crop | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Welsh onion | 100 | 110 | 136 | 146 | 123 | 143 | 151 | 127 | 129 | 126 | 125 | 106 |
| Carrot | 100 | 94 | 90 | 111 | 139 | 155 | 189 | 214 | 197 | 166 | 155 | 135 |
| Cabbage | 100 | 106 | 92 | 107 | 236 | 347 | 492 | 511 | 448 | 385 | 211 | 153 |
| Tomato | 100 | 107 | 83 | 97 | 155 | 176 | 236 | 314 | 351 | 302 | 253 | 175 |
| Kangkong | 100 | 101 | 100 | 86 | 73 | 62 | 69 | 74 | 60 | 67 | 87 | 103 |
| Wax gourd | 100 | 130 | 101 | 108 | 97 | 76 | 68 | 60 | 67 | 86 | 143 | 101 |
| Average | 100 | 108 | 100 | 109 | 137 | 160 | 201 | 217 | 209 | 189 | 162 | 129 |

[a] Monthly price index = [(average price of each month–average price in January)/100 + 1] × 100.

Despite the attested preference for safe products in the public media, it appears that demand for 'safe vegetables' remains modest. The reason may be that consumers are unaware of the availability of 'safe vegetables' or do not know where they are sold [24]. In addition, the lack of enforced quality standards and the absence of guaranteed quality indications on the product, encourages consumer's distrust of the origin of 'safe vegetables'.

For conventional vegetables, the producers and collectors deliver the vegetables to wholesale markets, where they sell the vegetables (1) to traditional retailers such as market retailers, who sell vegetables at city district retail markets, (2) to street vendors who sell vegetables at a fixed place in the streets, or who walk around with the products, (3) directly to consumers, (4) to restaurants, and (5) to hotels. Wholesalers are involved in trading vegetables produced in the RRD or in trading off-season vegetables from outside the RRD. In that case collectors sell the vegetables to the wholesalers, and then the retailers and the consumers buy the vegetables from wholesalers at wholesale markets [28]. At the retail-market level, most of the conventional vegetables are sold at traditional retail markets. The market share of traditional retail markets is 92%.

On the long term, the rise of supermarkets in Vietnam, from 1 in 1993 to 130 by the end of 2002, may offer new and potentially profitable methods of marketing for vegetables. On the short and mid-term the traditional retail system will remain the most important marketing channel [30].

In conclusion, the data indicate that most vegetables are traded through the traditional marketing channels, in which there are no fixed price agreements between producers, collectors or retailers. Consequently, producers depend on the prices offered by the collectors. Demand for 'safe vegetables' remains modest.

### 5.3. Vegetable prices

Prices of vegetables in the traditional markets vary with the season. In the hot season, notably in July and August, temperate vegetables such as cabbage, tomato and carrot fetch high prices in the Hanoi market (Table 6), since it is not possible to produce these vegetables in the RRD at that time [13]. Vegetables like kangkong (*Ipomoea aquatica*) and wax gourd fetch lower prices during the hot season (Table 6), as they grow and yield well at high temperatures [14], resulting in a large supply. In general, prices for vegetables are high from June through November as a result of the low productivity because of wet and hot weather conditions and because of the limited area of land used for vegetable production during summer [12].

In contrast, prices of vegetables in supermarkets are more stable. Vegetable prices in supermarkets do not drop sharply in the main season. Compared with the main season, prices in the supermarkets in the off-season are only 2% higher for tomato and 11% higher for kangkong [31]. However, because supermarkets supply only 1% of the vegetables traded in Hanoi, the vast majority of the vegetable producers in the RRD do not take advantage of the more stable prices of vegetables in the supermarkets.

In conclusion, vegetable prices for consumers vary during the year, as related to the seasonality of vegetable production.

### 5.4. Consumer perception of products

Many consumers believe that vegetables are unsafe because of chemical contamination. Being asked which foodstuffs were most dangerous to consumers' health, 89% of the respondents answered that vegetables were the most dangerous, followed by meat (70%), fruits (46%) and fish (37%). Among chemical contaminants, pesticides are a major concern, followed by growth regulators and overdoses of fertilizer [32]. This concern, however, has no discernible effect on vegetable consumption. Eighty-nine per cent of the Hanoi interviewees trust their own health and preparation practices to avoid health risks [32]. The criteria by which clients perceive vegetables to be good have been listed [27] as follows:

1. Desirable appearance, freshness, taste, tenderness and size.
2. Clean, healthy, good nutritional quality, locally grown during the main growing season, and grown in a healthy environment with minimal use of chemical agents.
3. Well preserved and well packed.
4. Good price.

In conclusion, despite the indicated distrust of the safety of conventionally produced vegetables, conventionally produced vegetables still make up the majority of vegetables sold.

## 6. Opportunities and constraints of vegetable production in the Red River Delta of Vietnam

### 6.1. Opportunities

Vegetable production in the RRD plays an important role in providing vegetables to the urban areas of the region. Among conventional vegetables traded in Hanoi, the leafy vegetables, such as kangkong, green choy sum, Indian mustard and lettuce, and summer fruit vegetables, such as wax gourd and yard long bean (*Vigna unguiculata* ssp. *sesquipedalis*), are all produced in the RRD. In their main season (November–January), temperate vegetables, such as tomato and cabbage, originate entirely from the RRD and in their off-season up to 11% [13]. Given the increasing urbanization in the RRD, the demand for vegetables is likely to grow.

Heavy rainfall and a high incidence of pests and diseases during the hot season may damage crops and reduce productivity. Protected cultivation in tunnels, plastic houses or net houses, could improve productivity and yield [4,8]. However, because of the insecure marketing conditions, farmers are reluctant to invest in protected cultivation.

Presently, mulching of crops is not common practice. Mulching, e.g., with rice straw or rice husks, material that is abundantly available, could help to reduce (1) leaching of nutrients, (2) soil surface erosion, and (3) labour demand for weed control, while at the same

time preventing soil surface compaction and adding organic matter to the soil.

Vegetable production in the RRD has advantages. Farmers can earn a higher income with vegetable production than with rice and corn production [12]. As continuous vegetable production brings in greater profits than the vegetable–rice–rice rotation [25], farmers may be stimulated to grow vegetables year-round.

Permanent vegetable production systems indeed may be an option to improve vegetable production systems in the RRD. By taking out flooded rice, permanent vegetable production systems may improve soil physical properties by eliminating the repeated wetting, puddling and drying of the soil, possibly resulting in greater yield stability and higher crop yields. In addition, it would reduce labour costs because of eliminating the need for raised bed construction and subsequent flattening after vegetable production. Permanent raised beds would be fixed in place, offering opportunities for long-term soil improvements.

An opportunity therefore would be to design, test and implement innovative permanent vegetable production systems for the RRD. Taking into account the agro-ecological conditions of the area and the potential of crop rotations in terms of product marketability, profitability and plant-health aspects, vegetable production systems could be designed to achieve the following objectives: (1) to facilitate year-round vegetable supply for the RRD's increasing population, (2) to increase the income of small farmers by growing potentially profitable crops, and (3) to improve soil conditions for better growth and yield stability of vegetables.

By designing and implementing systems that couple greater yield stability with better timed marketing and higher profits, farmers could gradually improve their position. With an improved financial situation and greater professional confidence, farmers would have the opportunity to get better organized, enlarge their operations in terms of hiring additional land and labour, and explore opportunities to improve their marketing.

Product prices influence the profitability of vegetable production in the RRD more than intensification of production would do [33]. In order to improve their bargaining position with collectors, wholesalers or retailers, growers would need to be able to offer their product in larger quantities and on a regular, planned basis. Farmers' participation in commercial co-operatives or producer organizations would be an option to achieve this goal. Further co-operative integration, involving exchange of land to obtain larger or neighbouring plots would open opportunities to work on a larger scale in order to reduce costs of operation. Furthermore, it may offer opportunities to collectively implement harvest date planning and product quality control and aim for integration of production and marketing in a value chain. The introduction of cool storage and transport would widen the choice of crops to grow and would reduce post-harvest losses.

For 'safe vegetables', although on a modest scale, there already are co-operatives that organize their own harvest planning, quality control, integrated pest management training and retailing, with farmers sharing the profits of joint activities [24].

### 6.2. Constraints

The seasonal variation in temperature in the RRD poses limits on the year-round production of vegetables of tropical or temperate origin. Presently, most of the vegetable crops are produced in the period with low temperatures. Heavy rainfall in the hot and wet period from May to September may cause low vegetable productivity because of mechanical damage and may result in loss of nutrients by leaching or surface erosion. Yield losses due to pests and diseases are higher in the wet season than in the dry season.

Flooded rice is the dominant crop in the period with high temperatures. This dominance exists because (1) national food security in rice was promoted by the government [7,34], and (2) farmers grow rice in the hot season to ensure that at least they will have enough food when other crops fail or when they lose other sources of income. This is especially true in the RRD, where the average area of agricultural land per capita is comparatively low. So rice contributes to the seasonality of supply and prices of vegetables because in the hot season most of the land is used for rice production.

Growing flooded rice has a negative effect on soil structure because of the repeated wetting, puddling and drying of the soil. In addition, the yearly build-up and break-down of raised beds requires high labour inputs.

High labour requirements and high costs of production may limit vegetable production. Production costs of vegetables are often twice as high as those of cereals [12]. Without some form of secure marketing, for most farmers vegetable cultivation is substantially more risky than rice, maize (*Zea mays* ssp. *mays*) and corn (*Zea mays* var. *rugosa*) production.

Urbanization and industrialization may negatively influence vegetable production in the RRD. Whereas peri-urban vegetable growers may have better connections to markets, consumers and knowledge [3] than their rural colleagues, they face higher risks in terms of pollution and the possibility of losing their land to urban and industrial development [22].

Product safety is becoming a major concern in society. Official protocols to produce vegetables and to control their quality are lacking, except for the comparatively small quantities of 'safe vegetables' produced by 'safe vegetable' co-operatives. Presently most of the vegetables produced in the RRD are produced conventionally with high inputs of pesticides [18]. Excessive use of organic and inorganic fertilizers may result in soil and water pollution [35] and high nitrate contents in vegetables. Samples of conventionally produced Indian mustard and green choy sum all had nitrate contents above the threshold level [8]. Consumers are concerned about pesticide residues, over-application of fertilizers and the use of growth regulators in vegetable production in the RRD [3,32].

The insecure marketing conditions have been considered the most important constraint on vegetable production in the RRD [15]. Because there are no contracts between producers and traders, except for the small amount of safe vegetables traded through co-operatives and distribution companies, producers depend on fluctuating free market prices. In general, the small vegetable producers are planning their operations without market information or product price agreements. Producers try to grow temperate vegetables as early as possible to benefit from the generally high prices in the period September–November. As a consequence, vegetables are sold at high prices when demand still exceeds supply, but they are sold at low prices, or may not be sold at all, when supply starts to exceed demand.

The small scale farming operations and the comparatively high costs of the marketing of only small amounts of product, limit the farmer in organizing his own supply directly to a retailer. The small amounts of product offered, and the perishable nature of the product, reduce his bargaining power with collectors, who try to maximize their own profit.

## 7. Analysis and pathways for sustainable development

We reviewed the available knowledge and documentation on vegetable production and marketing in the Red River Delta (RRD) of Vietnam in a holistic approach, covering climate, soils and socio-economic, agronomical and marketing conditions. Effects were summarised and, where applicable, categorised in opportunities and constraints. The result is a comprehensive multi-disciplinary overview. The emerging picture is that of an intricate system in

the sense that multiple physical and socio-economic factors simultaneously influence present vegetable production and marketing in the RRD. The challenge is to analyse and formulate pathways for sustainable development taking these multiple issues into account.

The physical constraints: less favourable soil conditions, high intensity rainfall and long distances to markets are considered mono-factorial issues, for which issues technical solutions, e.g. adapted fertilizer application strategies, protected cultivation and cold storage and transport, are available. The application of these solutions depends on the availability of the knowledge and materials for the farmers and on funds to invest in the necessary equipment [4]. Provision of government extension service and credit facilities would address these constraints. At a certain scale, this issue is being addressed by the Ministry of Agriculture and Rural Development of Vietnam [36].

The major constraint to development, i.e. the small landholdings and extremely small plots, resulting in small production volumes and consequently lack of control in marketing, is unique for South East Asia and of an intricate socio-economic nature. Its origin is found in the redistribution of land in separate quality categories to each family after de-collectivisation in 1988 [7]. An increase in rural population of 59% after collectivisation in the 1960s, contributed to very small plots allocated per family with de-collectivisation. This issue is not easy to address and no technical solution is available. Given the relatively new, and cherished, private land-ownership, enlarging land-ownership per family by buying, is not common. Also hiring additional land for vegetable production is not often found in the RRD.

To break the cycle of small landholdings, small plots, small product volumes and consequently lack of control of marketing, a solution would be to develop permanent vegetable production systems with farmers co-operating in producer organizations to enable production of vegetables across larger areas, resulting in greater volumes, with harvest date planning and quality control [4], and integration of year-round production with marketing in a vegetable value chain [37]. In recent years, on a small scale, a number of cooperatives that produce 'safe vegetables' have succeeded to build up regular supply to supermarkets, market stalls or shops, because they started to produce vegetables year-round and diversified their products [38]. The realisation of such an approach on a large scale goes beyond the organisational capacities of individual, small farmers. Co-operation between public (agricultural research and extension) and private (producer organisations, wholesalers, retailers) parties would be required. The emergence of supermarket retailing may offer opportunities to pioneer direct producer organisation-retailer marketing configurations [39]. The adoption of guaranteed Vietnam Good Agricultural Practices [40], will address consumers' food safety concerns. The increase in urban vegetable demand will be conducive to create new opportunities for the RRD vegetable producers.

As a first step in this approach, from the production point of view, we investigated the potential of permanent vegetable production in terms of profitability and the expected higher labour demand. From an analysis of three hundred sixty data sets of the production of 42 different vegetable crops in the RRD, it was concluded that permanent vegetable production has the potential to significantly increase household income, while increased labour demand can be absorbed within the family [41].

From the marketing point of view, a next step would be to investigate the opportunities in the RRD for setting up public private partnerships in order to structure vegetable production and marketing in vegetable value chains, benefitting all partners [37].

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